where concave glasses are necessary, even for near work, we may, by increasing the distance between the glasses, so that each eye shall look through the inner half of the glass, obtain an effect similar to that which would be produced by the combination of a prism, base inwards, with a concave glass; and if the lenses needed for such correction are of considerable strength, the prismatic effect which we can thus obtain may be sufficient for our purposes. We may, also, correct in this manner very satisfactorily that slighter excess of convergence over accommodation, which, as I have pointed out, may, under such circumstances, exist even for distant vision. In the slighter degrees, also, where total correction for near work may not prove acceptable, we may, by a partial correction and an eccentric position of the glasses, restore parallelism between convergence and accommodation and obtain very satisfactory results.

And here I would direct attention to the ill effects of a habit, which is only too common—that of wearing nose-glasses, for the correction of myopia for distant vision, the centres of which are often much nearer together than the centres of the pupils. As the result of this we have prismatic action the opposite of that just described, and necessitating, in order to overcome the diplopia which would otherwise result, a certain amount of convergence of the optic axes even for distant vision, with which an accommodation movement is associated, whereby the shortsightedness is not only temporarily increased but the progress of the myopia promoted. Though attention has been directed to this point before, it does not seem to have received the consideration which it deserves on account of its practical importance.

The division of the external recti muscles in muscular asthenopia in connection with progressive myopia, which has been recommended as a means of arresting the increase of the latter, is an extreme measure which, even where real insufficiency exists, it seems to me should be rarely resorted to, because, in most cases, the benefit to be derived from the operation may be obtained in a more satisfactory manner by the use of prisms; and where the insufficiency is the result of the anomaly of refraction, and, therefore, is only apparent, it is certainly not to be thought of.

BALTIMORE, Nov. 1, 1873.

ART. V.—*Some Points in the Mechanism of the Cranium considered with Reference to the Causation of Fracture.* By H. ALLEN, M.D., Professor of Comparative Anatomy in the University of Pennsylvania.

NOTWITHSTANDING the many learned essays which have appeared and the ingenious experiments which have been made with the object of illustrating the laws controlling the mechanism of the cranium, there yet remain some points requiring explanation. The cranium has been studied almost entirely (not to consider here questions of philosophical anatomy and ethnology) from the surgeon's point of view rather than the physiologist's. We have argued backward from the lesion to the normal structure, rather than, as we should have done, forward from the normal structure to the lesion. The force that breaks, or tends to break, is surely of less importance than the force that preserves from breakage. In a word, the study of the cranium as an organ designed to resist force has been neglected to the advantage of those studies in which the action of external force has been mainly concerned. Thus it was long ago observed that the wound made by a missile penetrating the brain case would be larger within than without; from which it was concluded that the inner plate was the more brittle of the two, and was in consequence named the vitreous plate. The fact established by Mr. Wm. Fred. Teevan,[1] that, if the missile be directed at the sides of the brain case from within instead of without, an opposite result was produced, proved that the question assumed had less to do with the skull as a physiological structure than it had with an isolated problem in dynamics.

Unfortunately the study of cases of fracture of the skull does not assist us in arriving at satisfactory conclusions as to the manner in which the skull has resisted a force from without. Such general facts as the ovoidal figure of the skull, the presence of spongy tissue at its base, the distribution of numerous sutures, etc., which may serve as non-conductors, will rarely apply to cases of fracture as seen in our hospitals or even in private life. Any one can satisfy himself of the truth of this by glancing at the reports of cases of this lesion. It is the exception rather than the rule to be assured, from the description given, as to what portions of the brain case the lesion may be sought for after death, or to explain their positions when they have been found. Every report should state not only the exact position of the body at the time of the accident, together with a description of the agent of force, whether a missile or the fall of the body, but some approximative estimation of the volume and kind of force. It is needless to say that an exact anatomical description of the injury, as studied on the dissecting table and from the skull subsequently, should be appended.

Few cases will stand this test. Until the record is fashioned differently from what we have found it, a study of the literature will yield no results of value.

We have been compelled, therefore, in approaching the subject, to tread on theoretical grounds, using analogy to support our position where demonstration fails.

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[1] "An Inquiry into the Causation, Diagnosis, and Treatment of Fractures of the Internal Table of the Skull," Brit. & For. Med.-Chir. Rev.," 1865, p. 189. Also, "Experiments and Inquiries into Certain Wounds and Fractures," Ibid. 1864.

The figure of the *cranium* is observed to be thinner at the anterior and posterior cerebral fossæ than at the middle fossa of that name. The region of the face underlies the first mentioned, the deep cervical muscles protect the second, while the middle receives within its base the enormously thickened "petrous bone."[1] At least these are the leading features of their respective regions. The anterior cerebral fossa is of unusual significance, since it is the weakest part of the cranium. Numerous cases have been narrated of fracture of the orbital plates by sharp or blunt instruments being thrust upward above the eye. Fractures of the same plates by indirect force extending from the cranial walls will be considered further on. If the bone at this region be examined, it will be found void of diploe. It is a suitable point, therefore, from which we may proceed to the remarks we have to make upon the distribution of this substance in the cranial walls.

The *diploe* is usually described as forming a layer of cancellated structure between the outer and the inner plates of the skull. It is very unequally distributed. It is massed at about the centre of the basi-cranial axis, on either side of the occipito-sphenoidal junction ; it passes backward and is abruptly lost in the compressed basilar process, but enlarges forward to enter the great wing of the sphenoid bone which it makes up in the main. A conspicuous collection exists in the occipital condyles ; another smaller one is found in the apical third of each petrous bone. Next we find the vault receiving a thin layer. Many parts of the skull are entirely free from diploe, as for example, the cerebellar fossa, the floor of the grooves of the lateral sinuses as they approach the base of the skull, the roof of the glenoid fossa, the greater part of the squama, the outer two-thirds of the petrous bone, and the orbital plates of the frontal bone. These parts are necessarily inherently weak, not from their several positions, but from the absence of the shock-distributing tissue, the diploe; and we infer that they must incur fracture when by accident they are compelled to bear the brunt of direct violence. Hence the weakness of the orbital plates as distinct from their relations with the face. Fracture of these plates is more frequently seen as a result of force applied upon the cranial walls than upon the facial.

It is well to remember that the names—the outer and inner plates of the skull—are more or less conventional. There is but one well-defined and constant plate, and that is the *inner*. The places at which the diploe is absent the outer plate may be said also to be absent, and the thinning at the points under observation is not so much due to the union of the plates as to the absence of one of them. The outer plate is well shown at about the osseous sinuses and the foramen magnum ; but throughout the vault it is less defined—and by the numerous veins seeking outlet from the diploe to the scalp—we have the outer plate in many places forming but a thin covering to the outer row of diploic cancelli.

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[1] By common consent the phrase "petrous bone" may be used in this connection for the cumbersome phrase, petrous portion of the temporal bone.

The contrast between the markings upon the two plates is great, while the markings themselves are independent of one another—so much so, indeed, that each must be considered separately. The inner plate is for the most part smooth. The sutural lines are not serrate. The digitate impressions and the associated ridges are peculiar to this plate. The outer plate is not marked by depressions, and its processes are entirely independent of the inner plate. From the above data we would submit the following: The inner plate is the true osseous envelope of the brain; the outer plate and diploe is but a single layer modified by muscular impressions, and by processes uniting the cranium to the face.

The force of a moderate blow upon the diploic layer does not tend to pass directly to the inner plate, but to radiate through the cancelli; and when the sutural markings remain, the force of the blow may be confined to the bone receiving the shock. Even when the shock passes thence, it is more reasonable to infer that the force is transmitted along the cancelli of adjacent bones than that it passes inward to the inner plate. Were it otherwise, fractures of the latter plate would be far more frequent. With a view of illustrating the distribution of force through the entire cranial figure, let us surmise that a blow has been received upon the right parietal bone. The serrated sutural lines between the opposite parietal and the portions of the frontal and occipital bones entering into the vertex tend to prevent its transmission either to the opposite side or to the forehead or occiput, while the squamo-parietal suture prevents its direct conduction to the ear. It is not prevented, however, from passing downward and forward along the anterior inferior process to the cancelli of the great wing of the sphenoid bone and thence to the body, or along the posterior inferior process to the mastoid region to be dispersed among the cancelli of the mastoid process, or on the occipital condyles. It will also be seen that lines of force sent along the angles of the parietal bone may be weakened before reaching the cancelli at the base by deflection across the inferior portion of the non-serrate parieto-occipital suture into the cancelli of the occiput, or forwards along the external angular process across the equally harmonic portion of the parieto-frontal suture.

The anterior inferior and posterior inferior angles of the parietal bone can be compared to pillars of a parietal half arch. Each pillar rests upon cancellated abutments. The anterior of these is supported by the frontal bone, and the posterior by the occipital bone.

The anterior parietal pillar, as it may be termed, has a peculiar arrangement with the orbital plate, which it will be remembered represents a portion of the inner plate of the cranium. An examination of the frontal bone shows that the inner plate of the cranium at the roof of the orbit is articulated with the outer third of the lesser wing of the sphenoid bone, and thence forms the bridge which, as a rule, converts the sphenoidal fissure into a foramen. It forms with the lesser wing the posterior edge of the anterior cerebral fossa. Now, the broad triangular space which lies between the external angular process of the frontal bone and the edge of its orbital plate is irregularly marked by the shelving layer of diploe, which corresponds to the surface of the great wings of the sphenoid bone. It is upon this surface that the outer edge of the orbital plate above described rests. Bearing in mind that this thin, hard, brittle plate rests upon an abutment of cancelli represented in the greater wing of the sphenoid bone, any shock transmitted downward along the cancelli of the vault to the region of the forehead would not injure the orbital plate, for the cancelli lies above its plane. But a shock sent along the inner plate would necessarily be received upon the orbital plate as representing the limit of the inner table anteriorly.

Let us suppose that a blow is received upon the occiput. It is easy to understand that the diploe may convey the shock to the anterior portion of the brain case without interference, and thence transmit it along the great wing of the sphenoid bone to the base. If the stroke upon the occiput be sufficiently severe to contuse the diploe through its entire thickness, the inner table is broken at a point opposite the contused portion. As is known, this contusion need not be direct, but mediate, when we may expect fracture of the inner plate only. As a rule, however, both plates are broken.

It can be conceived that a shock may thus be received upon the inner plate and transmitted along its entire length and finally expend its force upon the orbital plates. This would appear to be the explanation of the lesions found in the case of President Lincoln. A pistol ball penetrated the cranium one inch to the left of the median line of the occiput just above the groove for the lateral sinus. It thence passed forward in a straight line and lodged in the left striated body. Both orbital plates were fractured. Since these plates were not struck by the ball, it remained an open question how the fracture was produced. Professor T. Longmore,[1] of Netley, believes the lesions above described are to be attributed to a—

> "transmitted undulatory stroke or sudden impulse of the brain substance itself against the thin bony layers constituting the orbitar plates. I am in possession" continues he, "of the notes of a case in which a similar fracture took place in one orbitar plate, from a ball passing along only grooving the upper surface of the hemisphere lying over the plate broken."

Dr. George W. Otis, U. S. A., in the *Surgical History of the War of the Rebellion*, p. 306, accepts Prof. Longmore's opinion as being more satisfactory—

> "than the hypothesis that the fracture was produced by *contre-coup*. The unusually thin orbital plates on either side were exposed to the impulse of the cerebral pulp. Even if they were not fully protected from the vibrations in the

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[1] The Lancet, 1865, i. 649.

vault of the cranium, by the dense supra-orbital ridges, it might be inferred that the force would be transmitted mainly to the right orbital region, or that opposite the entrance perforation, whereas *both* orbital plates were fractured."

Among the reasons given by Prof. Longmore for believing that the shock could not be transmitted along the cranial walls is, "the expanse of the frontal bone itself and the several processes within which the orbital plates are held, and by which they are so strongly protected in all directions laterally."

If the proposition we have stated above, that the lines of conduction of force are different in the diploic layer from those of the inner, this layer cannot transmit vibrations to the processes. Neither does the inner table give to the diploe any vibrations which are primarily received within its compact tissue. A blow upon the cranium, say the occiput, awakens two distinct sets of waves; one of these moves along the diploic layer—and is lost in the processes, the other is carried by the inner plate to the anterior cerebral fossa.

Now, in the case of President Lincoln, the ball, not expending its force about the wound of entrance, yielded the greater part to both tables of the cranium. The outer diploic layer appropriated the vibrations, and transmitted them to the great wings of the sphenoid bone, and thence to the axis of the cranium, without injury to the skull. The inner plate, not having any means of diverting its burden of force, carried it forward in two divergent lines from the wound of entrance to the orbital plates (which lie, as is known, about on a level with the upper margin of the tentorium), and broke them. It is to be inferred, that, had the ball entered either above or below this line, the conduction of waves toward the forehead would have been greatly modified.

When the cranium receives excessive volumes of force, which it cannot disperse and yet preserve its integrity, we have presented for study some of the most frightful of lesions.

If our views concerning what we may term the parietal arch are correct, it will follow that the lines extending along the great wings of the sphenoid bone to the body, or along the mastoid portion of the temporal bone, thence across the occipital bone to the foramen magnum, would be frequent sites of fracture, resulting from the charging of the tracts with rays of force in excess. This, indeed, is the case. But the "petrous bone" is also found so often fractured that the escape of the sub-arachnoid fluid from the external ear, through fissures of the "petrous bone," is sought for as a sign of fracture of the base of the skull.[1] How can we explain that the part, which is apparently protected, is so often found fractured? We think, in one of three ways, as follows:—

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[1] In evidence of the loose method which apparently satisfies the describer of these and similar lesions, we may mention the phrase, "fracture of the petrous portion of the temporal bone," which we see used so often. When we recall the exceedingly diverse elements entering into this region—the dense walls inclosing the labyrinth, the spongy tissue at its apical third, the wafer-like covering of the cavity of the tympanum, and the irregular portion of the tubal and carotid portions—the above phrase, used unqualifiedly, is very indefinite.

First, by premising the exertion of such violence that analysis is defied—the literal mashings of the skull we sometimes see when scarcely a bone entering into the base will escape. *Secondly*, by exceptional conditions of the skull, especially diseased conditions, when propositions based upon the normal distribution of the cancelli and compact tissue are much disturbed. In hyperostosis of the cranium we find the diploic layer everywhere exaggerated, coincident with an increase of the number and strength of the inner plate, which present everywhere a great increase of the number of the digitate depressions and ridges.[1] Syphilitic osteitis is especially liable to weaken the vault of the cranium by eburnation of the cancelli, when the diploe of the great wing of the sphenoid bone often becomes compact with early obliteration of the spheno-parietal and spheno-frontal sutures. *Thirdly*, by the force being received primarily upon the base, as when the subject of the fracture falls from a height in such a way that the base of the skull becomes a fixed point upon which the body is thrust with great force.

The fracture arising from this last-mentioned cause is worthy of a more-extended mention. Dr. Hinton, in his Lectures on the Cranium,[2] says that the transmission of vibrations from the occipital condyles in the direction above mentioned—

> "accounts for the fracture through the petrous portion of the temporal, that is so often observed as a concomitant of a severe diffused blow on the top of the head, such as is incurred on falling to the ground from a height.
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> "That this is really an explanation of the cause of the frequency of the fracture occurring through the petrous bone, in such cases, is, I think, sufficiently proved by the following experiment, which suggested itself to me, and which I performed a short time since relative to this subject.
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> "Having fixed an ordinary adult skull on a firm support, with its vertex downward and its base upward, I placed a strong piece or bar of wood across the occipital condyles, and then, by means of a hammer, applied a stout blow, as evenly as possible, over its centre. The result of this, as I expected, was fracture through the petrous portion of the temporal, the line of fracture intersecting the *membrana tympani*."

From the rude experiment here resorted to, Mr. Hinton infers that the force of the blow, received at the base of the skull in life, is comparable to that transmitted from a *flat* surface. This is evidently a misconception. The occipito-atloid articulation is convexo-concave, and the weight of the head is supported, not so much at the centre of the facet, as it is upon points of contact before and behind that centre. As is known, the occipital condyle presents two facets—an anterior and a posterior. They are subject to great variation. In some specimens the outlines of the facets are but faintly separated from one another when the entire condyloid surface looks like a single facet, or they may be made distinct by a wide sulcus between them. The posterior facet is nearly circular in shape; the anterior is elliptical. In the accident Mr. Hilton's experiment is designed to explain, it is not probable that both these articular surfaces receive a shock at the same time. If the head were raised, the posterior facet would surely receive the brunt of the shock. If, on the contrary, the head were flexed, the anterior portion would receive it. It is also well to bear in mind that the plane of the condyle is oblique to the plane of the basial axis of the skull. The antero-posterior axis of the condyle converges toward the median line at the same time that the articular surface is tilted outward and downward. The weight, therefore, is received upon the atlal facets in such a manner that the skull is pressed *downward* and *outward*, and not directly downward, as is generally supposed. As a result the atlas gives a little lateral support to the condyles in addition to receiving and transmitting the weight downward to the superior articular facets of the axis. The lines of weight finally converge from the lateral to the median parts of the last named bone, and from that point the weight of the head is borne upon the bodies of the vertebral column. Accepting these lines as representing the normal distribution of the weight, it is only necessary to reverse the position to explain the fractures in the position named by Mr. Hilton, viz., the skull being fixed and the body thrust into its base. The weight of the body being represented as a unit of force divides at the axis into two—one for the left, the other for the right axal facet, thence to the atlas, which in turn transmits them to the occipital condyles. Here each again divides, one for the outer and the other for the posterior facet, both of which, resting, as they do, upon the abundant cancelli, tend to disperse much of the force, and the skull escapes injury. If, however, the volume of force is so great that it cannot be so dispersed, the posterior facet will transmit to the post-atlal region, and the skull be here fractured, or the anterior will send it upward and inward toward the basicranial axis, where by their convergence will actually tend to cancel one another. If, however, the force be excessive, the two ultimate lines will cross at the median line, and, pursuing the direction of greatest vibration, will reach the petrous portion of the temporal bone, with the destructive result so often seen after falls from a height upon the vertex. It will then be seen that the mechanism of fracture from this position is much more complicated than Mr. Hilton would have us believe.

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[1] There is a specimen of this disease showing these conditions in the Wistar and Horner Museum.

[2] Notes on some of the Developmental and Functional Relations of Certain Portions of the Cranium, London, 1854, 60.

The subject is one of great complexity, requiring careful analyses of many cases before determining a single point. Until such exhaustive study shall have been instituted, we must rest satisfied with theory based upon examination of normal structures.